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ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on the concept of "electric current" held by 43 elementary school pupils and 2 teachers college students. Data were obtained by the "interview-about-instances" procedure in which students were shown cards with diagrams which represented different instances and non-instances of the concept. Responses are presented, discussed, and analyzed in relation to: (1) scientific viewpoint of electric current; (2) non-scientific views, considering nature of electricity, current direction, and others; (3) where electric currents are found; and (4) influences of children's egocentric and human-centered viewpoints. A theoretical consideration of electrical current and implications for science instruction based on findings are included. Among the findings are those indicating that knowing/agreeing with statements (such as "In a metal an electric current is a flow of electrons.") may not substantially change a person's concept, and that many students associate presence/absence of electric currents with whether or not they can feel the current. (Interview cards used and summary of other research studies are included in appendices.) (JN)

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ELECTRIC CURRENT

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WORKING PAPER No. 25

In our view successful science teaching requires an appreciation not only of the scientists' view of the world, but also an appreciation of the language, the beliefs and the expectations which children bring with them to science classes. This working paper has developed from a study carried out in the in-depth phase of the Learning in Science Project and is one of a series of papers which explores aspects of Children's Science (see Working Paper No. 14). It is our hope that these papers portray children's views of the world and meanings for words in a way which will be useful to teachers and to curriculum developers.

In the action-research phase of the project it is our intention to attempt to build practical and useful teaching strategies based on the findings of the in-depth phase of the project. For this reason we are actively seeking comments on the findings we have detailed, and seeking information on the variety of ways teachers develop ideas associated with the topic under focus in this paper.

We would be grateful if comment and/or information could be forwarded to

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ELECTRIC CURRENT

A Working Paper of the Learning in Science Project

Roger Osborne

December 1980

INTRODUCTION

This investigation describes the concepts of 'electric current' held by 43 pupils and two secondary teachers college students. The pupils were:

4 Std 4	pupils (typically aged 10)	- code numbers 001 - 004
6 Form 1	pupils (typically aged 11)	- code numbers 101 - 106
6 Form 2	pupils (typically aged 12)	- code numbers 201 - 206
6 Form 3	pupils (typically aged 13)	- code numbers 301 - 306
6 Form 4	pupils (typically aged 14)	- code numbers 401 - 406
8 Form 5	pupils (typically aged 15+)	- code numbers 501 - 508
6 Form 6	pupils (typically aged 16+)	- code numbers 601 - 606
1 Form 7	pupil (typically aged 17+)	- code number 701
2 Teachers College	students	- code numbers T1, T2

The Form 5 pupils were all taking School Certificate Science. Apart from two of the Form 6 pupils who were studying Form 6 Chemistry (605 and 606) all of the Form 6 and 7 students were studying Physics. The two teacher trainees were Science graduates but had not majored in Physics. The pupils came from six different schools. Twenty-one of the 43 school pupils were female, as were the two science graduates. The pupils chosen were of average general ability according to their teachers. However, in our view, one or two of the junior pupils were well above average with regard to their scientific understanding.

The method of obtaining data, as in the other similar studies we have done in the in-depth phase of the Learning in Science Project, was an interview about instances approach. The method is detailed elsewhere[1] and is based on the supposition that a particular concept held by a person can be explored by asking a person to distinguish between instances and non-instances of the scientifically-accepted concept and by asking them to give the reasoning behind their action. In an individual interview situation, pupils were shown diagrams on cards (one per card) which involved a variety of situations which may or may not involve the presence of an electric current. The interviewees were then asked whether or not in their meaning of electric current there would be a current in the situation shown. This was then followed by "why do you say that?" or "tell me about that". All interviews were audio-taped and the recording later transcribed.

The cards used in the interviews are detailed in Appendix 1. They were identical to those used in an exploratory study of the interview about instances method carried out with John Gilbert at the Institute for Educational Technology, University of Surrey in 1978/9[2].

THE SCIENTIFIC VIEWPOINT OF ELECTRIC CURRENT

The questions asked and the scientifically acceptable responses to the interview cards are set out in Appendix 1. Typically for any one card some 30% of students gave responses which would indicate an adequate scientific perspective. However, it is interesting to note such responses were not confined to older students, neither did the same students consistently respond from the scientific perspective.

The following responses, to the question about whether there was an electric current in the situation shown, indicate the scientific viewpoint.

---

1 Gilbert, J.K. and Osborne, R.J. "I understand but I don't get" - some problems in understanding science. School Science Review, 61, 217, 1980, 664-674.

2 Osborne, R.J. and Gilbert, J.K. An approach to student understanding of basic concepts in science, Guildford, UK; IET University of Surrey, 1979.

"No, it has to be connected to something."
(Battery 1; 105[3], 106, 203, 204, 205, 306, 401, 403, 406, 502, 504, 507, 508, 601, 606, T2)

"No, there isn't because there can't be a current flowing around .. it has got to be a continuous circuit."
(Bare Wires; 202, 203, 204, 501, 601, 605, 606, T1, T2)

"No, it's magnetism in the compass needle not electricity."
(Compass; 004, 001, 002, 003, 102, 304, 503, 504, 505, 506, 601, 701)

Students also gave other responses which indicated an appreciation of the fact that electric current flows around a circuit and is the same magnitude at all points in the circuit.

"Yes, it goes from the battery into the liquid and back to the battery."
(Liquid; 103, 003, 401, 404, 405, 501, 508, 605)

"All the torch batteries would have the same current in them."
(Torch; 106, 202, 206, 302, 305, 401, 502, 504, 602, 603, 604, 605, 701, T1, T2)

Asked where the electric current into the lamp goes (Card No. 5), 12 students stated that it goes around the circuit,

"It goes back through the wires."
(Lamp; 103, 203, 301, 305)

"It goes around the circuit."
(Lamp; 401, 202, 403, 404, 504, 603, T1)

---

3 The first code number is that of the student who made the stated response. Other students quoted gave similar responses.

Very few responses (approximately 2 to 3%) referred to electrons or charged particles. For example,

> "No, because there is no flow of electrons, it's just static, there's nothing actually flowing through it."
> (Battery 1; 501)

> "Yes, there will be electrons in the gas."
> (Neon; 504)

At the end of the interview schedule students were asked to state explicitly what they considered an electric current to be. Approximately 50% of students gave a reasonably scientific statement; a higher percentage than might be expected in terms of the number of good scientific responses to the interview cards. Examples of explicit statements about electric current were,

> "A flow of electricity." (203, 303)

> "Electricity going through something ... like water current ...with still water there is no current ... but when it is moving there is." (001)

> "A flow of electrons." (507, 602, 604, 606, T1, T2)

> "A flow of electrons in one direction."
> (501, 504, 506, 601, 605, 701)

> "So many charged electrons passing through a point."
> (502)

One of the strengths of the interview about instances method is the ability of the procedure to expose students' viewpoints, whatever these viewpoints might be. In this section we have stated that typically 30% of students responded with a scientific viewpoint with respect to any particular card while some 50% of students could provide an adequate scientific definition of an electric current. What is of perhaps greater interest in terms of gaining insight into pupils' problems with this concept, and what we will now explore in some depth, is the non-scientific viewpoints about electric current that children hold.

WHAT IS AN ELECTRIC CURRENT? - THE NON-SCIENTIFIC VIEWPOINTS

(a) Electricity

Electricity is a rather vague term in a scientific sense. In common usage it has a variety of meanings as we will explore later. Many younger children appeared to use the word electricity when asked about electric currents as if both words meant the same thing. The children tended to use electricity in a way compatible with viewing it as an electrical fuel or energy.

"Yes, the battery forms a source of electricity."
(Battery 1, 003, 101)

"No, because it is gas ... electricity would heat the gas which would put the light on." (Neon, 001)

"Yes, because you need electricity to make it go."
(Neon, 205)

"No, (but) there is electricity in the sun which gives off heat and light." (Sun, 406)

"Yes, something is making electricity when the clouds crash."
(Lightning, 404)

"No, because he's not generating any electricity."
(Writer, 501)

Two third form students (301 and 302) when asked for a definition of electric current simply stated "electricity".

One fourth form girl (406) continually responded in terms of electricity, i.e. whether electricity was present or absent, throughout the interview. When this point was explicitly discussed at the end of the interview it became clear that the student was quite unaware she had continually talked about 'electricity' while the interviewer had continually talked about 'electric current'.

(b) Electrical energy, fuel or charge

While many students did not use the word electricity, 50% of the students interviewed tended to view electric current as something that can be stored in a disconnected battery (Card No. 1).

Subsequent interviewing revealed that many of these students appeared to consider electric current as a type of energy or electric fuel.

> "Yes, if you put it in a car the electric current would run out and help start the car." (Battery 1, 001)
>
> "I think so although it's using up its energy (which battery [connected or unconnected battery] has the greater electric current?) the unconnected one" (Battery 2, 301)
>
> "Yes, because you need one of those [batteries] to make the car go." (Battery 1, 402)
>
> "Yes, because it has got to produce one to go out ... so it's got to have one in it." (Battery 1, 505)

In giving a definition, eight students explicitly stated that electric current was a form of energy or power.

> "It's a form of power that makes things go." (Definition, 103, 401, 404, 406)
>
> "It's a form of energy." (Definition, 202, 205, 505, 508)

Three students tended to equate electric current with electric charge. This view is not very different from electric current being considered 'electricity' or 'electrical fuel' in that it is viewed as something which is stored.

"Yes, because there is a negative and a positive."
(Battery 1, 206)

"Yes, layers of positives and they are separated by lead."
(Battery 1, 404)

"Yes, there must be electrons in the battery."
(Battery 1, 605)

While the above students did not consider that the electricity (energy or charge) needed to be flowing to constitute an electric current, others seemed to see a distinction.

"Yes, (there is a current in the battery) but it's not moving because it is not connected up."
(Battery 1, 303)

"Do you mean an electric current or an electric current flowing?" (Bare wires, 606)

An example of how prevalent the view is that an electric current can be present in a disconnected circuit, consider Table I where the summary of responses to the bare wires situation (Card No. 3) is given. Nine students gave a scientifically acceptable response, 13 students responded with a subjective view which reinforces the idea that a current can exist in this situation, some seven students considered the current just flows out the bare prongs, while 12 considered the current is in the prongs but is not flowing[4].

---

4 The remaining four views were more idiosyncratic and less easily categorised.

TABLE I: The Bare Wires

Scientifically acceptable responses

"No, there isn't because there can't be a current flowing around it ... it has got to be a continuous circuit."
(202, 203, 204, 501, 601, 605, 606, T1, T2)

Commonsense views

"Yes, if you can touch it you get a shock."
(001, 003, 103, 205, 206, 401, 405, 505, 701)

"Yes, if there was a bulb there it would glow."
(002, 102, 105, 402)

The "leaky tap" response

"Electric current is still flowing out of the bare prongs."
(502, 004, 304, 305, 403, 506, 603)

It's "just there" response

"Yes, if there isn't a light bulb, there are still currents in the prongs."
(406, 104, 201, 302, 303, 404, 503, 504, 507, 508, 604, 606)

(c) Electric current as a flow of electrical fuel

We have observed that to some pupils an electric current is equivalent to electrical fuel. In addition to these students, there is another group who view it as the flow of electrical fuel. To both these groups an electric current is something which flows from a battery or power source and "used up" or "transferred to other forms of energy" in a light bulb or other electrical device.

The most noticeable situation in which this view was detected was in the situation of the lamp (Card No. 5) where the question "Where does the electric current which goes into the lamp go to?" was asked. Replies related to the fuel viewpoint were,

"It gets used up." (Lamp, 104, 205, 402, 502, 506, 508)

"It gets burnt up." (Lamp, 106, 302)

"It's transferred into light." (Lamp, 101, 303, 501, 505, 602)

"It's transferred into light and heat energy." (Lamp, 503, 601, 701)

As we discussed earlier only some 11 students stated the electric current goes back around the circuit.

In the situation where students were asked about which battery in the torch (Card No. 11) has the most current through it, over 50% of students responded that No. 3 had the most current[5],

"No. 3 because it would have the electricity from 1 and 2, and it's own electricity." (Torch, 001, 002, 102, 204)

"No. 3 because (the current) from No. 1 and 2 join together going through No. 3." (Torch, 003, 101, 103, 104, 105, 201, 203, 205, 301, 303, 304, 306, 402, 403, 501, 505, 508)

"No. 3 because the power from the other two are going through that." (Torch, 406, 503, 506, 601)

Again this view implies the idea that electric current makes a one-way trip from battery to bulb (a unipolar viewpoint).

---

5 Knowledge doesn't necessarily change a person's viewpoint as exemplified by the following quote:

"No. 3 ... if there are 1.5 volt batteries, then there would be a 4.5 volt light bulb ... so the first battery would have a current of 1.5 volt ... the second would be 3 volts and the third would be 4.5 volts, I think." (Torch, 606)

(d) Electric current in a circuit

We have seen that children have at least two views about the direction of current in a circuit; the scientific viewpoint that electric current flows around the circuit in one direction and a non-scientific view that the electric current makes a one way trip, for example from the battery to the bulb. One might argue that surely older students appreciate that a completed circuit is required for the bulb to light. While this is quite probable it does not necessarily mean that they will change their intuitive view substantially. Studies in France (see Appendix 3) suggest that some children hold a unipolar view despite their knowledge that two wires are required for the bulb to light. The second wire simply acts as a necessary but passive link.

Apart from these two viewpoints our studies, as well as those in France, reveal a third viewpoint. This viewpoint was first noticed in our study when one interviewee who, although he appreciated that a complete circuit was required for a current to flow, suggested that in the case of the torch (Card No. 11) batteries No. 1 and No. 3 would have the most current.

> "No. 1 goes one way, No. 3 goes the other way and No. 2 feeds into both of them." (Torch, 405)

In some of our interviews - unfortunately not all - students were asked about the direction of the current in the short wire providing the return path from liquid to battery (Card No. 10). While five students (103, 205, 305, 404, 605) stated the current went from liquid to battery, ten students (104, 105, 106, 204, 206, 303, 402, 406, 603) stated it went from battery to liquid in both wires. Their responses to the initial question "Is there a current in the liquid?" reinforced this view,

> "Yes, the battery is sending electric currents through the wires and into the water." (Liquid, 105, 104)

> "Just the current coming off the rods into the water (would it be coming off both rods into the water?) Yeah ... the water might be absorbing some of the current." (Liquid, 603)

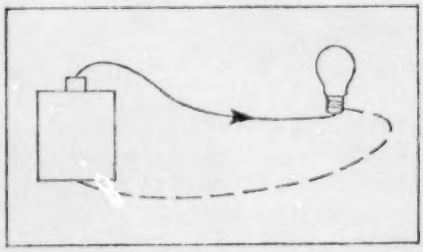
Two students, when asked to state explicitly what an electric current is, referred to the idea of two things being brought together.

"Two separate forces of energy which go together and make an electric current ... (what is an electric current?) energy"
(Definition, 104)

"Two things clashing let out an electric current ... just a force ... an argument between forces."
(Definition, 306)

One is left with the distinct impression that although students may consider a closed circuit is required for a current to flow, the direction in which this flow is envisaged may well be different in many pupils' minds from that required by the scientific perspective. Some of the different viewpoints that children do hold about currents in simple circuits are summarised in fig. 1.

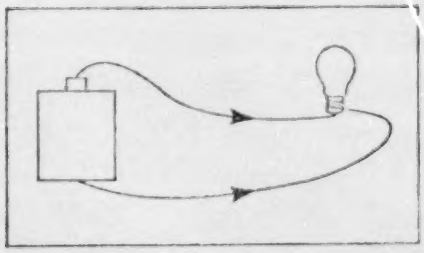
View 1 (Unipolar)



"Electric current is the connection between battery and bulb." (11 yr old)

"Electric current gets used up in the bulb." (11 yr old)

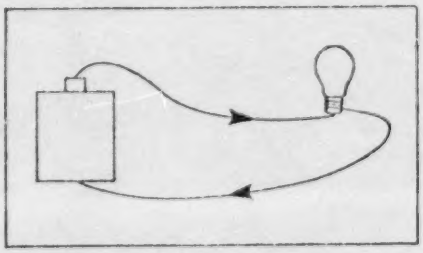
View 2 (Bipolar)



"Two separate forces of energy which go together and make an electric current." (11 yr old)

"Two things clashing let out an electric current." (13 yr old)

View 3 (Scientific)



"Electric current goes on around the circuit." (14 yr old)

"Electric current carries on to other parts of the circuit." (14 yr old)

Fig. 1: Childrens' views of electric current in a simple electric circuit.

WHERE ARE ELECTRIC CURRENTS FOUND?

While, from the scientific viewpoint, electric currents are considered to exist wherever there is a flow of electrical charge, this viewpoint is not necessarily shared by children.

(a) A limited concept

In the experience of many children electric current, or electricity, is primarily associated with batteries, wires and electrical equipment found in homes. This is reflected in such comments as,

> "No, electric current is man-made."
> (Sun, 205)

> "No, there is no electricity in the sun and there is no way it can get from the sun." (Sun, 202, 203)

This view was also held by a few advanced students,

> "No, I think of a current having to pass through some sort of physical medium rather than zip through space down to earth."
> (Sun, 604)

> "No, because there is a vacuum and electric current couldn't flow through a vacuum." (Sun, T1)

Similarly this limited view was evident in discussions about whether there was an electric current in the writer's arm[6] or in a compass needle,

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6 On the other hand, two students displayed good knowledge and thinking when confronted by the question of current in the writer's arm,

> "Depends on what you mean by electric current ... the nerves in the arm are worked by electrical impulses."
> (Writer, T1)

> "Yeah ... there are nerve impulses in the person's arm ... but even scientists are not sure [whether they are electric currents] ... some of them think it's chemicals ... some of them think it's electrical ... it just depends on your point of view."
> (Writer, 604)

"No, he's got muscle, he doesn't need electricity to move his arm." (Writer, 002, 105, 404, 406, 505)

"No, I don't think people have electricity in them." (Writer, 305, 001, 004, 204, 205, 303, 405, 504, 508)

"No, because there is nothing like a battery or anything to produce an electric current." (Compass, 204, 508)

One natural phenomena which was invariably considered to have an electric current in it was lightning. Seven students (2xS3, 1xF1, 1xF2, 1xF5, 1xF6, 1xT) said they had read about it in a book or implied that they had learnt about it,

"Yes, I read about the guy who flew a kite." (Lightning, 508)

Nine students (1xF1, 1xF3, 5xF4, 1xF5, 1xT) went further and offered a detailed explanation, for example,[7]

"When two clouds crash together it causes lighting." (Lightning, 104)

"Yes, because clouds create an electrostatic force and an electrostatic current." (Lightning, 504)

The remainder of those interviewed reasoned that lightning was an electric current because you got a shock if you touched it and/or it was capable of burning holes in things.

(b) An over-generalised concept

In general, as outlined in the last section, the concept of electric current tended to be under-generalised in that it tended to be restricted to technological examples, apart from lightning.

On the other hand approximately 30% of those interviewed considered magnetic effects as found in a compass needle may be something to do with electric currents. While this is not entirely incorrect (see Appendix I) the associated comments revealed some confused thinking;

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7 The particular views quoted reinforce the bipolar viewpoint about circuits.

"Yes, well I think electricity causes the needle to move."
(Compass, 104)

"It depends if it is an electric compass or a magnetic one."
(Compass, 101)

"Yes, it magnifies an electric current."
(Compass, 401)

"Not in the needle but somewhere in the pin."
(Compass, 405)

"Yes, there is an electromotive force that makes the magnet point North." (Compass, 501)

"Not really a current, the needle is sort of charged."
(Compass, 502)

These responses indicate half-learnt scientific ideas and compare poorly with the answers of some Standard 4 students whose views were much more scientifically sound.

"No, all there is is a magnetic force ... that's all it needs."
(Compass, 001)

"No, it's magnetic." (Compass, 003, 002, 004)

As we have noted elsewhere in this series of working papers, as teachers we need to be particularly careful that in teaching some ideas - for example, the magnetic effects of electric currents - we do not introduce confusion with regard to associated ideas, e.g. ideas about magnets.

(c) Concepts and definitions

While language becomes more sophisticated with increasing age of the interviewee, and while rote learnt definitions are more often found in the older students repertoire, any particular viewpoint can be found at almost all age levels, as we have found in our other investigations. Compare the following answers of a Form 2 student (202) and a Form 7 physics student (701),

"No, there isn't because there can't be a current flowing around ... it has got to be a continuous circuit."
(Bare wires, 202)
"Yes, it would give you a shock."
(Bare wires, 701)

"The electric current leaves the lamp and goes back to the power source." (Lamp, 202)
"The electric current is transferred as energy ... like light and heat energy." (Lamp, 701)

"No, because the compass works on magnets and although the metal is moving around the magnet it is not moving enough to make an electric current ... (you see) if you get a magnet and move it fast around a coil or wire or move a coil of wire around a magnet then there is an electric current."
(Compass, 202)
"No, not really ... it's magnetised."
(Compass, 701)

"They would all have the same because the currents going through ..." (Torch, 202)
"I think it may be the same." (Torch, 701)

As exemplified by the above responses, the 12 year old had a much sounder concept than the 7th form physics student. However given a situation where the student is asked for a definition of electric current, the 7th form student would appear to have a better understanding,

"An energy form I suppose ... I don't understand it ... but I know that it makes lights work and motors turn around and stuff like that."
(Definition, 202)
"I would say it is a flow of electrons."
(Definition, 701)

This comparison reinforces our view that the ability to provide acceptable definitions and the acquisition of a useful scientific concept are <u>not</u> the same thing. We need to find out what concepts children have, and we need to help them refine or modify these concepts, rather than simply encouraging them to acquire definitions.

In a subsequent phase of the interview those students who stated that they were familiar with the statement "in a metal an electric current is a flow of electrons" answered some further questions. Their responses to some of the questions are provided in Appendix 2 and reinforce the point that knowing, or agreeing with, a definition may not substantially change a person's concept.

INFLUENCES OF CHILDREN'S EGOCENTRIC AND HUMAN CENTRED VIEWPOINTS ON THEIR IDEAS ABOUT ELECTRIC CURRENT

As we have described in our other investigations in this series[8] we have continually been reminded that children frequently view the world from a very self-centred and human-centred viewpoint. One aspect of this viewpoint is found in the common children's view that if something cannot be directly perceived with one of the five senses then it doesn't exist. Alternatively if it can be sensed, then it does exist. It is not surprising, therefore, to find that, in their reasoning about the existence or absence of electric current, children place a great emphasis on whether or not you can feel an electric current.

Nine students (2xS3, 2xF2, 2xF4, 1xF5, 1xF7) argued that there was an electric current in the bare wires (Card No. 3) because "if you touch it you get a shock."

Ten students used similar reasoning with respect to the lightning,

"Yes, if someone was struck by lightning they would be electrocuted." (101, 306)

"Yes, if you touch it you get a shock." (103, 105, 402)

"Yes, because you get a shock if it hits you." (301, 303, 305, 603)

"Yes, you can get killed by lightning ... just like a shock." (701)

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8 See Working Papers No. 15-24.

In our earlier study in England, we were told that there couldn't be a current in the writer's arm because "you couldn't feel a current." One Form 2 student had similar problems in this investigation,

> "Perhaps without it (an electric current) you couldn't make your arm move ... on the other hand if there was an electric current you probably couldn't live."
> (Writer, 201)

Whether there was a current in the liquid was related by two students to human experiences,

> "Yes, like when power lines fall on (wet) ground you get a shock." (Liquid, 303)

> "Yes, you can be electrocuted having a bath." (Liquid, 406)

Over 50% of those interviewed (1xS4, 4xF1, 4xF2, 5xF3, 3xF4, 6xF5, 1xF6, 1xF7) argued that there was an electric current in the electric fence because you would get a shock if you touched it. Some experiences were obviously very real,

> "Yes, because it hurts ... it's horrible ... you get a shock and you are shaking like anything."
> (Lightning, 402)

This dramatic and widely known effect of electric current on humans probably has a big influence upon children's thinking about the subject of electricity and as we have seen this thinking does not always lead to a scientific perspective, particularly about electric current.

THEORETICAL CONSIDERATIONS AND IMPLICATIONS FOR TEACHING

Electric current is defined in the Shorter Oxford Dictionary as the flow of electricity. This "definition" can be also found in junior science textbooks. Unfortunately the word electricity does not have a precise meaning in science apart from being the name of a branch of science, namely that which deals with electrical phenomena. In science electric current is commonly defined as the flow of electric charge, so presumably those who state "electric current is a flow of electricity"

are using the word "electricity" to mean electric charge. However there are other meanings for electricity in common usage[9], namely

(i) the electrical attraction between bodies;

(ii) Franklin's imaginary fluid which was supposed to explain electrical phenomena;

(iii) the energy released by the movement of charged particles.

What, then, does the definition "electric current is a flow of electricity" imply to some people - "the flow of energy", "the flow of a fluid", or even "the flow of a force"? It is perhaps not surprising that we have found some children with each of these views.

More correctly, in a scientific sense, electric current is defined as the charge per unit time passing through a given area, e.g. the cross sectional area of a wire. We might therefore talk about the electric current across a particular area in a particular direction. However, even textbooks which define electric current in this way tend to use the term "electric current" more loosely as a "flow of charge". While it might be argued that electric current is something measured across a surface and doesn't go anywhere, even advanced physics textbooks[10] refer to "electrical currents flowing into a junction", "the total current from the battery" and "the sum of the currents going into a junction". Here the word "current" is used to mean "charges per second" and we have been guilty of using it in this way in our questioning, viz. "Where did the electric current which goes into the lamp go to?". Does this commonly used language in textbooks and in our teaching tend to reinforce the idea which some children have that electric current is the same as electric charge, in the sense that if you can have an electric current flowing into something you can presumably have an electric current which is not flowing?

While the basic concept of electric current once understood is a simple concept, it is perhaps not surprising that students have difficulties. It is an abstract concept: we can't see electric current, hear it, smell it or taste it. On the other hand sometimes we can feel it and this unfortunately leads to as much confusion as it does to clarification.

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9 See Shorter Oxford Dictionary and Heinemann New Zealand Dictionary

10 See typical first year University physics textbooks, e.g. Orear p.348, Warren p.309-310.

In teaching about electric current we undoubtedly use the term in situations where it would be more appropriate to talk about 'charges' or 'charges per second', e.g. "the electric current comes out of the battery". Possibly in so doing we reinforce the intuitive children's science view that electricity, and even electric current, is a tangible substance which goes from the battery.

Do we stress sufficiently that electric current or electric charge is not used up in a light bulb or motor, while electrical energy is used up.

Have we insufficiently stressed water and gravitational analogies of electric circuits in recent years? While the danger in using such models has been emphasised by some educators, have the dangers of not presenting children with any relatively concrete model on which to hang their ideas been fully appreciated? For example, has the absence of such models led to students simply retaining their earlier intuitive ideas?

Many of the children's ideas considered in this paper we also found in our study in England. Certainly if we have a problem it is not just a local one.

ACKNOWLEDGEMENT

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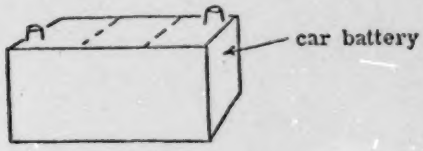
Appendix 1: The Interviewer Cards and a Physicist's Viewpoint

1. Battery 1

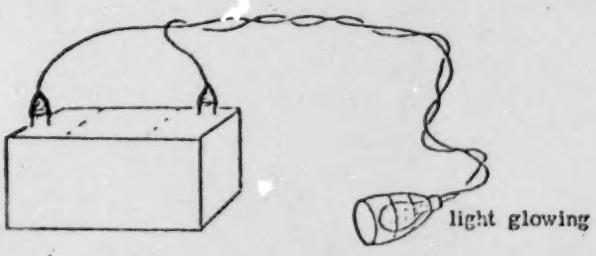


Is there an electric current in the battery?

A Physicist's view

"No, I don't think so ... there may be some minor currents that are not supposed to be there. The battery is a store of electrical energy but there is no flow of charge."

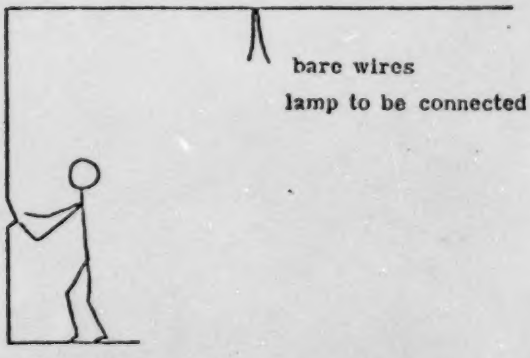
2. Battery 2



Is there an electric current in the battery?

"Yes, there will be an electrical current in all parts of the circuit including through the battery. The current will be the same in all parts of the circuit, and the charges flow around the circuit."

3. Bare Wires

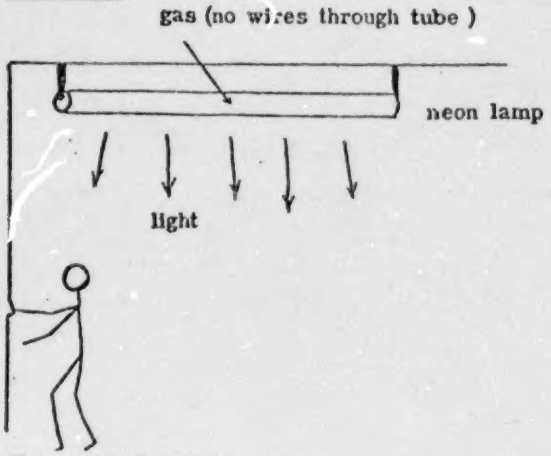


The switch is on.

Is there an electric current in the bare wires?

"No, the circuit is not complete so charges cannot flow. A current would flow if the two bare wires were connected."

4. Neon

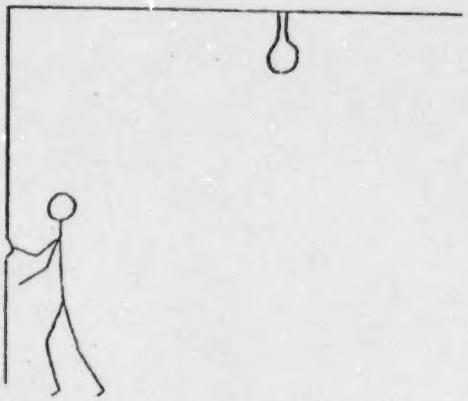


"Yes, electrons move through the gas colliding with the neon gas particles. These collisions result in the gas emitting light."

The neon lamp is on.

Is there an electric current in the lamp?

5. Lamp

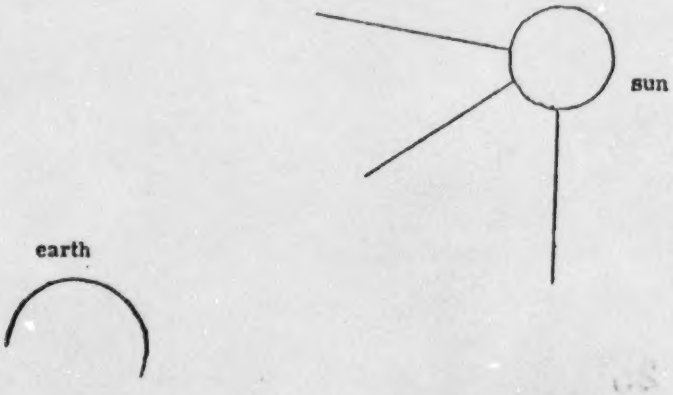


"Yes, the electric current is the same in all parts of the circuit. There are as many charges/sec entering the lamp by one wire as there are leaving the lamp by the other wire."

Is there an electric current in the lamp?

Where does the electric current, which goes into the lamp, go to?

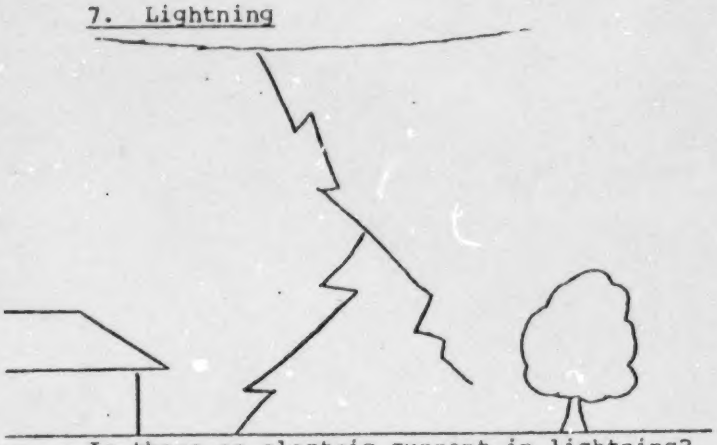
6. Sun



"The sun emits charged particles, e.g. electrons and so on, some of which reach the earth. In that sense we might consider there to be an electric current. However, heat and light from the sun are in the form of electromagnetic waves. These have no electric charge and therefore do not form an electric current."

Is there an electric current from the sun to the earth?

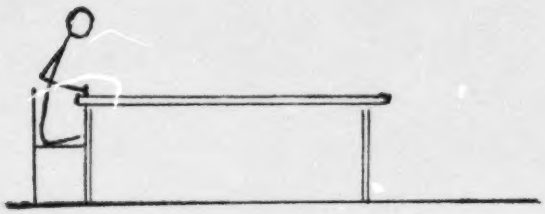
7. Lightning



Is there an electric current in lightning?

"Yes, charged particles travel between clouds, or between the clouds and the ground, in a lightning flash. Therefore this constitutes an electric current."

8. Writer



A person is writing at a desk.
Is there an electric current in the writer's arm?

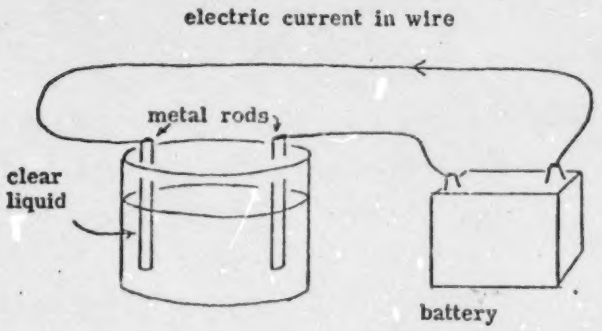
"Nerve impulses travel from the brain to the arm. These are called electro-chemical impulses and result in minor movement of charged particles in the nerves. In that sense we might consider them to constitute an electric current."

9. Compass

Is there an electric current in the compass needle?

"Not really. It is magnetised. Physicists talk of equivalent electric currents called magnetisation currents in the magnetic material but these are electric currents in a sub-atomic sense only."

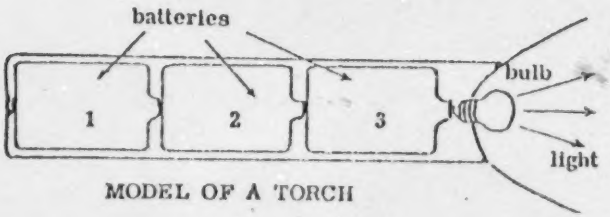
10. Liquid



"If there is a current in the long wire there must be an equal current in all parts of the circuit. The liquid must be a conductor otherwise there would be no current in the wire. In the short wire the direction of the electric current is from rod to battery."

There is a current in the wire.
Is there an electric current in the liquid?

11. Torch

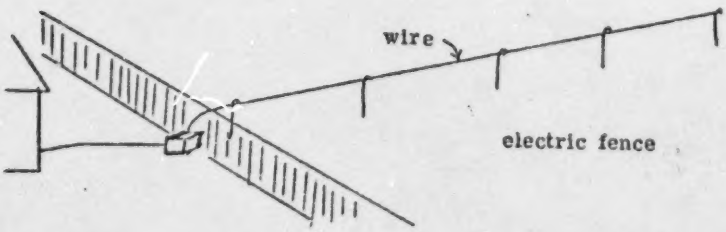


MODEL OF A TORCH

"Yes, all batteries have the same current through them as they are all connected into the same circuit. The currents in all parts of the circle will be the same."

The torch is switched on and the lamp is glowing.
Is there an electric current through the batteries?
(If so), which battery has the most current through it?

12. Fence



"Unless a circuit is created by someone touching the wire and completing the circuit through the ground, there is no electric current in the fence wire."

The electric fence is turned on.
Is there an electric current in the fence wire?

13. How would you define an electric current?

"An electric current is a flow of electric charge. More precisely the electric current through a given area is the nett positive electric charge passing through that area/sec (plus the nett negative charges/ sec passing in the opposite direction)."

Phase II - In a metal an electric current is a flow of electrons

"There are free electrons in all parts of the circuit. When the switch is turned on these free electrons all tend to drift around the circuit due to the presence of an electric field set up by the mains supply."

The switch is on and electrons start to flow into the lamp.

Where do the electrons come from?

Where do the electrons go to?

What causes the electrons to move?

Appendix 2: "In a metal an electric current is a flow of electrons"

Almost invariably it was only the students in Form 5 and above, who said that they were familiar with the above statement and agreed with it. Their responses to the following questions, No. 14 in Appendix 1, are summarised below,

Where do the electrons which go into the lamp come from?

"They are already in the wire." (403, 501, 504, 604, 701, T2)

"From the switch." (602, T1)

"They are built up in the battery ... stored ready for use." (303)

"Power supply." (502, 503, 505, 506, 507, 601, 606)

"I don't even know where they come from." (605)

Where do the electrons in the lamp go to?

"They just keep going around the circuit." (604, 605, 606, 701, T1, T2)

"They emit all their energy and just keep going around the circuit." (501)

"I suppose they get used up." (504, 603)

"They are used up to generate heat and light." (506)

"They are converted into energy." (502)

"Transformed into heat and light energy." (601)

"Split up ... bits of electrons are probably sent out with the light." (505)

"I think they burn into positive ions and just go into the atmosphere." (507)

What causes the electrons to move?

Heat (501, 603)
They are being pushed (505, 604)
Power (507)
Vibrations (503, 605)
I don't know (502, 602, 603, 606)
Energy (T2)

Appendix 3: Other studies of electric current

Investigations which have been undertaken in other countries to find out children's views on electric currents and/or electric circuits include:

(a) Osborne and Gilbert (1979) in England, who used the same deck of cards that were used in this study. The findings of that study are remarkably similar to the findings in the present study. Although English children interviewed may have been more talkative than the New Zealand children, there is little to distinguish between the two groups in terms of the range and type of replies.

(b) Tiberghein and Delacote (1976) in France, investigated children's ideas about electrical circuits. They found that 7-12 year old children had definite ideas about how an electric current flows in a circuit. Three distinct views were held.

(i) The electricity simply went from source to the electric device. Both battery and lamp, for example, really each only need one terminal to operate successfully (the unipolar model).

(ii) In this view, two wires are recognised as being necessary from battery to lamp but in both wires the electricity moves to the lamp where clash and causes the lamp to light (the bipolar model).

(iii) The electricity circulates around the circuit.

(c) Russell (1980) in South East Asia, investigated children's ideas with respect to aspects of electric circuits rather than electric currents. Like the French study he found the unipolar model of electricity flow was a "prevailing and persisting interpretation of the functioning of electric circuits by elementary school children".

The above work reinforces the view of Russell and Sia (1980) when they state "In researching children's belief systems ... it emerges that although there is individuality, there is not anarchy. Children are actively socialised into adulthood. Language practices and school experience itself all contribute to their beliefs; more fundamentally, pupils share certain biological and neurological predispositions of behaviour and perception. It should be no great surprise that as well as uniqueness, we find much common ground within a culture (and probably between cultures also)."

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